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HIGH DYNAMIC RANGE IMAGE PICKUP DEVICE
[Kou dainamikku satsuzou souchi]

Hisakazu Yoneyama

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INVENTOR	(72):	YONEYAMA, HISAKAZU
APPLICANT	(71):	Nikon K.K.
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[Claims]

[Claim 1] High dynamic range image pickup device comprising a nondestructive image sensor having plural light-interception elements, read control means that repeats the reading process for a specific number of times while the image sensor is exposed, level comparison means that sequentially compares the read output level of each light-interception element of image sensor with the specific standard level, data memory means that stores a value corresponding to the read output level when the read output level of said light-interception element exceeds the standard level for the first time, counter memory means that stores a value corresponding to the number of reading repetition performed until the read output level exceeds the standard level for the first time, and computation means that acquires the image output by extrapolating the value corresponding to the output level stored in the data memory means based on the value corresponding to the specific reading count and repeated reading count stored in the count memory means.

[Claim 2] High dynamic range image pickup device according to the claim 1, wherein said specific standard level is a value exceeding 1/2 of the saturation level of light-interception element.

[Claim 3] High dynamic range image pickup device according to the claim 1 or 2, wherein the number of read operations performed before the current reading operation is compared with the value corresponding to the repetition count stored in the count memory

means in order to determine the light-interception element output level having exceeded the standard level for the first time.

[Detailed Explanation of this Invention]

[0001] [Field of the Invention]

The present invention relates to a high dynamic range image pickup device and is particularly associated with a device that can pick up an image (e.g., still image or semi still image having significant luminance gap) within a wide dynamic range with excellent accuracy.

[0002] [Prior Art]

Fig. 5 is a diagram showing the configuration of known image pickup device including an image sensor. With this type of device, output signals generated from each picture element (i.e., light-interception element) configuring an image sensor corresponding to the image light guided to the image sensor **1** are sequentially read out, amplified by an amplification circuit **2**, and inputted to A/D converter **3**. This input signal is converted to digital data by the A/D converter **3** and stored in a memory **4**. A control circuit **5** performs control operations. For example, it sequentially reads out a signal from each light-interception element of image sensor **1** and writes it to each address of memory **4**. For example, the image data stored in the memory **4** as described above is read out by a computer (not shown in the figure), processed, and displayed on a display device.

[0003] [Problems to Be Solved by this Invention]

This type of known image-pickup device reads out image signals generated by simultaneously exposing every light-interception element practically for a single time. Therefore, the dynamic range of image pickup device cannot be widened.

[0004] The detail of this problem will be explained below with the reference of Fig. 6 exhibiting the relation between time and output level of light interception element of usual image sensor. That is, Fig. 6 shows the relation between time and output levels of light interception elements **A**, **B**, **C**, **D** that respectively receive image lights having different strengths. As shown in the figure, when the image sensor is read out at time **T**, the output $V_{A,1}$ of picture element **A** and the output $V_{B,1}$ of picture element **B** can be read out in the normal manner. However, the output $V_{C,1}$ of picture element **C** and the output $V_{D,1}$ of picture element **D** cannot be accurately read, as they are below the noise level V_0. Also, when the output is read at time **2T**, although the output $V_{B,2}$ of picture element **B** can be accurately read, the output $V_{A,2}$ of picture element **A**, which has reached the saturation level V_2, cannot be accurately obtained. In addition, the output levels of picture elements **C** and **D**, which are below the noise level, cannot be accurately obtained for the reason described above.

[0005] On the other hand, when the output is read at time NT by setting a sufficient accumulation time, although output $V_{C,N}$ of

picture element C and output $V_{D,N}$ of picture element **D** can be read out, output level $V_{A,N}$ of output **A** and output level $V_{B,N}$ of output **B**, which reach saturation during the process, cannot be accurately read out.

[0006] Therefore, the read-out method of known image pickup device is restricted by the saturation level for the high intensity direction (i.e., direction of bright light), whereas the output of low intensity direction (i.e., direction of weak light) is limited by the noise level. Hence, the maximum dynamic range of image pickup device controlled by the dynamic range of the light interception element of image sensor is limited to approx. several thousands times at most.

[0007] The object of present invention is to provide an image pickup device that can obtain a wide dynamic range without being restricted by the dynamic range of light interception element of image sensor, so as to solve the problems of the known devices.

[0008] [Method to Solve the Problems]

To achieve the object as described above, the present invention provides a high dynamic range image pickup device comprising a nondestructive image sensor having plural light-interception elements, read control means that repeats reading for a specific number of times while the image sensor is exposed, level comparison means that sequentially compares the read output level of each light-interception element of image sensor with a specific standard level,

data memory means that stores the value corresponding to the read output level when the read output level of said light-interception element exceeds the standard level for the first time, counter memory means that stores the value corresponding to the number of repeated reading operations performed until the lead output level exceeds the standard level for the first time, and computation means that acquires the image output by extrapolating the value corresponding to the output level stored in the data memory means based on the value corresponding to a specific reading count and the number of repeated read operations stored in the count memory means.

[0009] [Operation]

With the configuration as described above, the readout control means reads out each light interception element for a specific number of times while the image sensor is exposed. Then, the level comparison means compares the readout output level of each light interception element with a standard level, and when the readout output level exceeds the standard level for the first time, a value corresponding to the readout output level is stored in the data memory means, and the value corresponding to the number of previous readouts is stored in the repetition count memory means. Then, with the completion of readouts performed for a specific number of times, the computation means acquires the image output by extrapolating the value corresponding to the output level stored in the data memory means based on the value corresponding to a specific read-count and

the number of repeated read operations stored in the count memory means.

[0010] With this technique, an output exceeding the noise level can be obtained by setting sufficient accumulation time for extremely low intensity signals. Also, for a picture element receiving high intensity light to cause saturation during the accumulation process, a value reflecting the true output level can be obtained by extrapolating the data prior to the saturation stored in the data memory. Therefore, the dynamic range can be drastically widened regardless of limitation of light interception element characteristic.

[0011] [Operational Example]

The following explains the operational example of this invention while referring to the figures. Fig. 1 is a diagram showing the configuration of high dynamic range image pickup device used in the Operational example 1 of this invention. The device shown in the figure comprises an image sensor **11**, amplification circuit **12**, A/D converter **13**, data memory **14**, count memory **15**, counter **16**, comparison circuit **17**, multiplication/division circuit **18**, and control circuit.

[0012] The image sensor **11** is a nondestructive sensor and contains numerous light interception elements. The amplification circuit **12** is for buffering and amplifying the output of the image sensor **11**. The A/D converter **13** sequentially converts the readout outputs of the image sensor being amplified by the amplification

circuit **12** to digital values. The data memory **14** is a memory device that stores values for each picture element based on the digitized readout output level provided by the A/D converter based on the output from the comparison circuit **17**. The counter memory **15** is controlled according to the output of the comparison circuit **17** and stores the number of readouts for each picture element, counted until the output level of light interception element exceeds a specific value. The counter **16** counts the readouts. The comparison circuit **17** compares the digitized readout output level of light interception element with a specific value. The multiplication/division circuit **18** is a computation circuit that multiplies and divides for computing the final output. The control circuit 19 supplies a clock pulse and control signal to the circuit block and controls their operations.

[0013] The following will explain the image pickup operation as described above by referring to the flowchart shown in Fig. 2. Prior to reading out of image sensor, the control circuit **19** sends a reset signal so as to set the counter **16** to zero and stores the maximum repetition count **N** to the area corresponding to every light interception element.

[0014] Next, the control circuit **19** sends an increment signal and increment the counter **16** by 1. That is, the counter **16** is set to 1, indicating the first readout. In this condition, the output of each picture element of image sensor **11** is sequentially read out, and the readout signal is amplified by the amplification circuit **12**.

Then, the data is converted to a digital value using the A/D converter.

[0015] The output digital value of A/D converter **13** is expressed as $V_{j,k}$, which is compared with the standard value V_1 by the comparison circuit **17**. Note that 'j' denotes the picture element number of image sensor **11**, and 'k' denotes the readout count. That is, $V_{j,k}$ is the 'k'th output of the 'j'th picture element. For example, when the comparison result of comparison circuit **17** indicates that the output $V_{j,k}$ exceeds the standard value V_1 as was the case of first readout output $V_{A,1}$ shown in Fig. 6, the readout count **k** (1 in this example) is stored in the area corresponding to the readout light interception element of the count memory. That is, the value is set as $N_j = k$. In this case, N_j is the data of 'j'th picture element stored in the count memory. Furthermore, this readout output value $V_{A,1}$ is stored in the area corresponding to the picture element **A** of the data memory **14** (i.e., $M_j = V_{j,k}$), whereas M_j is the data in the data memory **14** of the jth picture element.

[0016] On the other hand, when the first output does not exceed the standard value V_1, such as picture elements **B**, **C**, and **D** in Fig. 6, the respective output values $V_{B,1}$, $V_{C,1}$, $V_{D,1}$, of picture elements **B**, **C**, and **D** are stored to the corresponding areas in the data memory **14**. In this case, since writing is not performed to the corresponding area in the count memory **15**, the maximum readout count **N** is left in the memory. With the completion of readout for every picture

element, 1 is added to the counter **16** to change the counter value to 2 for starting the second readout.

[0017] During the second readout, the output of light interception element of each picture element of image sensor **11** and count memory **15** are sequentially read. For example, although the output $V_{A,2}$ of the picture element **A** shown in Fig. 6 exceeds the standard value V_1, the value N_A in the corresponding area in the counter memory **1** has been set to "1" by the initial readout, and does not contain **N**. Therefore, data is not stored in the data memory **14** or counter memory **15**.

[0018] On the other hand, when the readout output $V_{B,2}$ of picture element **B** exceeds the standard value V_1, since the area in the counter memory **15** corresponding to the picture element **B** has N, the readout count k=2 is stored in the corresponding area in the counter memory **15**. That is, the stored data V_B in the area corresponding to the picture element **B** of counter memory **15** becomes "2".

[0019] However, since the readout output values $V_{C,2}$ and $V_{D,2}$ of picture elements **C**, **D** in Fig. 6 do not exceed the standard value V_1, those output values $V_{C,2}$ and $V_{D,2}$ are stored to the corresponding area of the data memory **14**. Note that the stored values in the counter memory **15** are not modified.

[0020] The operation described above is repeated for N times by sequentially incrementing the value of the counter **16**. As a result, $V_{A,1}$ $V_{B,2}$ $V_{C,N}$, $V_{D,N}$ are stored in the corresponding areas of data memory

14 for each picture element **A**, **B**, **C**, and **D** at the end of the process, whereas 1, 2, N, and N are stored in the counter memory **15**.

[0021] Next, the multiplication/division circuit **18** computes the output of each picture element. That is, when the output of picture element **j** is V_j, the following formula can be used to compute the output:

$$V_j = (N/N_j) \cdot M_j$$

As shown in Fig. 3, this formula obtains the output V_j at Nth readout (after the exposure time NT) by extrapolating the output M_j stored in the data memory.

[0022] In the example shown in Fig. 6, the final output V_A of picture element **A** becomes $V_{A,1} \cdot N$, and the final output V_B of picture element **B** becomes $V_{B,2} \cdot N/2$. Also, the final output V_C of picture element **C** becomes $V_{C,2} \cdot N$, and the final output V_S of picture element **D** becomes $V_{D,N}$.

[0023] Since the output of picture element having saturated during accumulation can be obtained by extrapolation, the dynamic range of image sensor itself can be drastically (i.e., to N times) expanded. For example, if N=1000, the dynamic range which is several thousands times greater than the range of image sensor itself can be expanded for thousand times, thus acquiring the dynamic range expanded for several million times.

[0023] Also, the standard value V_1 is preferably set to approx. 1/2 of the saturated output level V_2. This is because the level

allowing the prediction of exceeding the saturation point at the next read out when the output level exceeds the standard value exceeds V_1 is used as a standard level. Without saying that the standard level is not limited to approx. 1/2 of the saturation level V_2, as any level is applicable.

[0024] Fig. 4 is a diagram showing the configuration of high dynamic range image pickup device used in the operation al example of this invention. With the device shown in the figure, the output of image sensor **11** is inputted to a data processing device such as microcomputer **20** via an amplification circuit **12** and A/D converter. The microcomputer **20** is operated by the internal program executing the procedures shown in Fig. 2.

[0025] The device shown in Fig. 4 is conveniently used for the application such as astronomic observation that requires a lengthy total accumulation period for the image sensor, and the readout speed of the first exposure may be slow. This application can simplify the circuit configuration compared with the device shown in Fig. 1.

[0026] [Effectiveness of this Invention]

With the method based on this invention explained above, when the signal is weak, an output higher than the noise level can be obtained by setting a longer accumulation period. Also, for strong signals, the final output can be obtained by extrapolating data based on the value obtained within the short accumulation time prior to the saturation of interception element output. Since the essential

dynamic range of image sensor can be drastically expanded by this technique, an object with a significant luminous intensity gap can be accurately picked up.

[Simple Explanation of the Figures]

[Figure 1] is a diagram showing the configuration of high dynamic range image pickup device used in the Operational example 1 of this invention.

[Figure 2] is a flowchart explaining the operation of image pickup device shown in Fig. 1.

[Figure 3] is a diagram exhibiting the computation method of final output performed by the multiplication/division circuit of the device shown in Fig. 1.

[Figure 4] is a diagram showing the configuration of high dynamic range image pickup device used in the Operational example of this invention.

[Figure 5] is a diagram showing the known configuration of image pickup device including an image sensor.

[Figure 6] is a graph exhibiting the relation between time and output levels of light interception elements.

[Explanation of Keys]

11…Image sensor; 12…Amplification circuit; 13…A/D converter; 14…Data memory; 15…Counter memory; 16…Counter; 17…Comparison circuit; 18…Multiplication/division circuit; 19…Control circuit; 20…Micro computer.

Figure 1

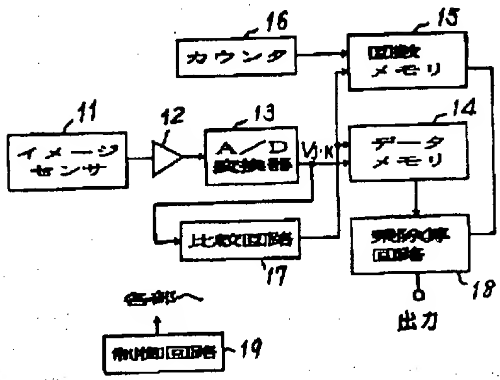


Figure 3

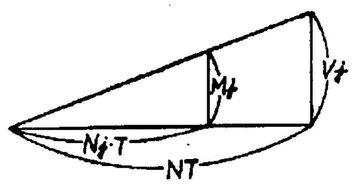
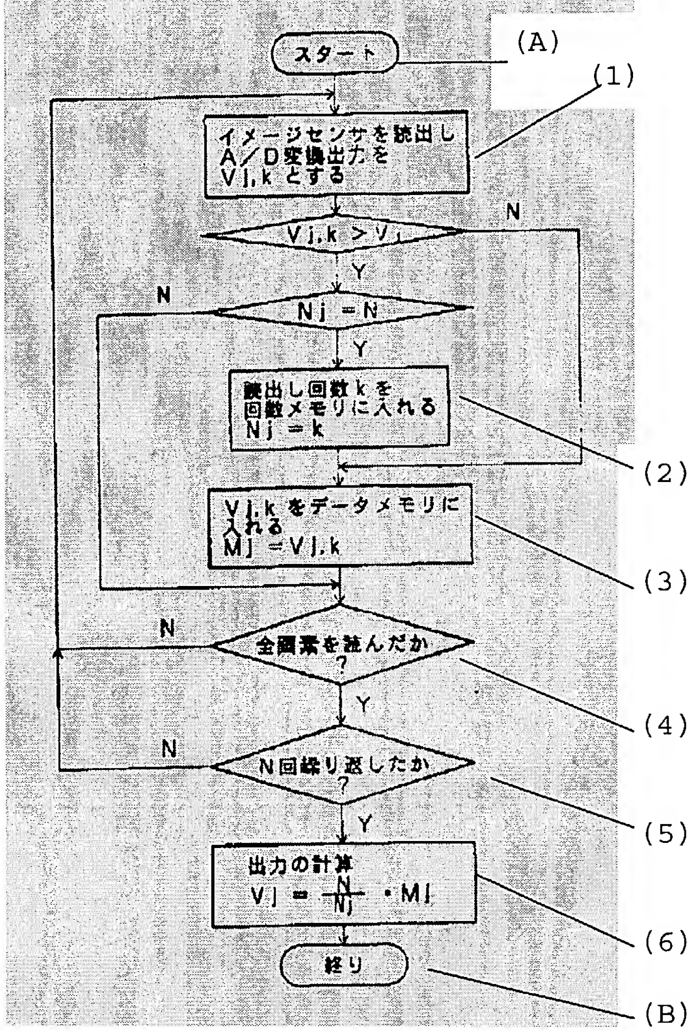


Figure 2



Key A…Start; B…End; 1…Read out image sensor and set A/D conversion output to Vj,k; 2…Store readout count k to count memory; 3…Store Vj,k to data memory; 4…Was every picture element read?; 5…Repeated for N times?; 6…Output computation

Figure 4

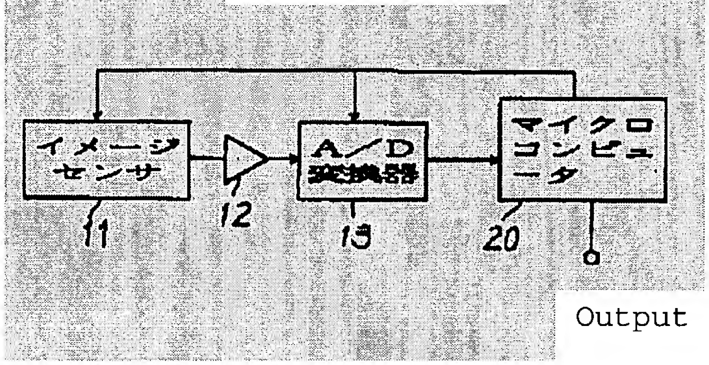
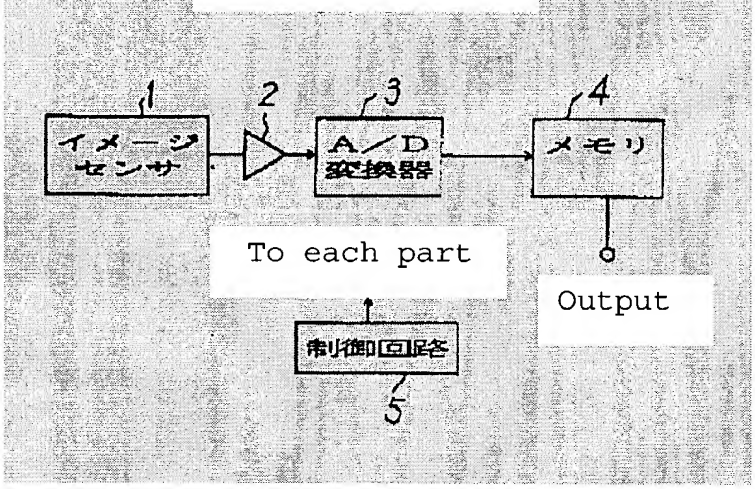
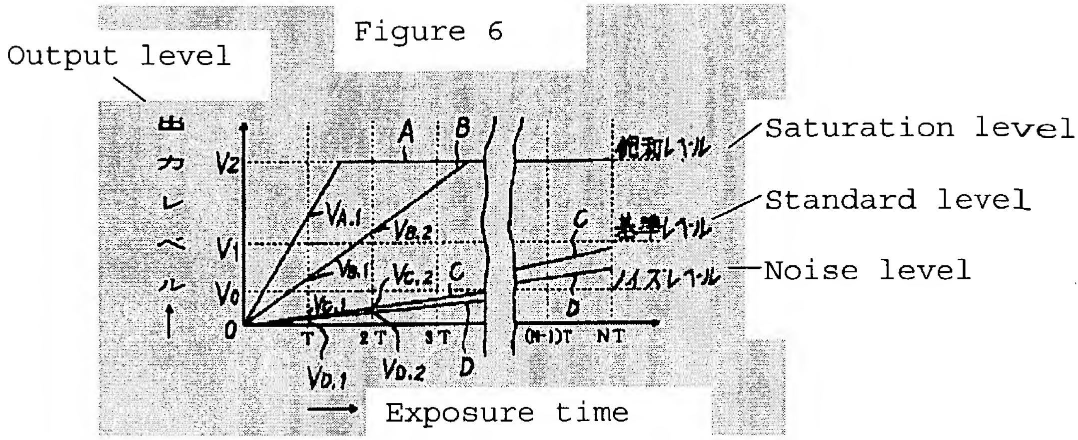


Figure 5



Key 1…Image sensor; 3…A/D converter; 4…Memory; 6…Control circuit

Figure 6



Output level
出力レベル
V2
V1
V0
0
A
B
C
D
$V_{A,1}$
$V_{B,2}$
$V_{B,1}$
$V_{C,2}$
$V_{C,1}$
$V_{D,1}$
$V_{D,2}$
T
2T
3T
(N-1)T
NT
飽和レベル
Saturation level
基準レベル
Standard level
ノイズレベル
Noise level
Exposure time